SPECIFIC ANTIBODIES AND ANTIBODY FRAGMENTS FOR TGFβ1

This application claims priority from US provisional application
60/131,983 filed April 30 1999, whose contents are hereby
5   incorporated by reference in their entirety.

Field of the Invention.

The present invention relates to specific binding members,
particularly antibodies and fragments thereof, which bind to
10   transforming growth factor 1 (TGFβ1). More particularly, the
invention is concerned with specific binding members which include
the VH CDR3 of the antibody SL15 (the antibody formerly known as
Kylie), especially the SL15 VH domain, which may be in combination
with the SL15A or SL15S VL domains. Furthermore, the invention
15   relates to use of such specific binding members in pharmaceutical
preparations, particularly for the treatment of fibrotic disease,
the modulation of wound healing and the treatment of cancer.

Background to the Invention.

20   PCT/GB96/02450 published as WO97/13844 discloses the isolation of
human antibodies specific for human TGFβ1 and human antibodies
specific for human TGFβ2. It describes antibodies with the 31G9
VH domain and variants of the domain. More specifically the
application described the antibody CS37 that comprises the 31G9
25   VH domain together with the CS37 VL and variants of this domain,
including antibodies which:
(i) compete in ELISA with CS37 for binding to TGFβ1,
(ii) bind TGFβ1 preferentially with respect to TGFβ3, and
(iii) neutralise TGFβ1.

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Disclosure of the Invention.

The present invention is based on identification of antibodies
which are related to CS37, but which have unexpectedly

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advantageous properties with respect to binding and neutralisation of $TGF\beta_1$. They do not bind to, or neutralise, $TGF\beta_2$ or $TGF\beta_3$.

Antibodies of the present invention strongly neutralise active $TGF\beta_1$. The epitope for these antibodies lies in the C-terminal region of $TGF\beta_1$ (residues 83-112) and includes the loop consisting of residues 92-98 of $TGF\beta_1$, also known as finger 2, a region which has been identified as interacting with the receptor for $TGF\beta$. The antibodies bind preferentially to active $TGF\beta_1$ with respect to latent $TGF\beta_1$.

Variants of SL15S that strongly neutralise $TGF\beta_1$ are also disclosed herein. These vary mainly by amino acid substitutions in the CDR3 of VH or VL domains. There are, however, other sites where substitutions may be made, e.g. at residue 25 in the light chain an alanine may be substituted, generating the IgG4 antibody, SL15A IgG4, CAT-192. Several substitutions may be made that are compatible with the retention of strong neutralising activity. The antibodies of this invention will be particularly useful for treatment of fibrotic diseases, e.g. lung fibrosis, modulation of the scarring response, e.g. in wound healing and corneal scarring, and in other contexts discussed further below such as the treatment of tumours.

Specific binding proteins such as antibodies which are based on the complementarity-determining regions (CDRs) of the advantageous antibody VH and VL domains identified herein, particularly the CDR 3 regions, will be useful for the purposes discussed, and represent aspects of the present invention.

The most preferred embodiments of the present invention in its various aspects are based on the VH CDR3 of the SL15 VH domain

identified herein, VH domains including the SL15 VH CDR3, especially the SL15 VH domain itself, and pairings of such VH domains with VL domains, especially the SL15A or SL15S VL domains, or other VL domain comprising the SL15 VL CDR3. The antibody antigen-binding domain SL15 (in whichever format, e.g. scFv or IgG4) consists of the SL15 VH and, in two variants, either the SL15A VL (CS37) or SL15S VL (CS37 with A25S). In either variant, SL15 is the antibody formerly known as Kylie. SL15S scFv is also known as CAT 191; SL15A IgG4 is also known as CAT-192; and SL15S IgG4 is also known as CAT-193.

Further embodiments of the invention in its various aspects are based on the JT182 VH CDR3, VH domains including the JT182 VH CDR3, especially the JT182 VH domain, and pairings of such VH domains with VL domains, especially the CS37 VL domain. JT182 is not as effective as SL15, but still has unexpectedly improved properties over CS37.

In a first aspect the present invention provides an isolated specific binding member capable of binding TGFβ$_1$, wherein said specific binding member comprises an antigen binding domain comprising a VH CDR3 with an amino acid sequence substantially as set out as VH CDR3 of SL15 or JT182 in Table 1 or Table 2.

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Table 1: Anti-TGFb1 Clones CDR3s & Relative Potencies of scFv

CLONE	Approx IC_{50} (RRA)	VH CDR3	VL CDR3
CS37	10-15nM	TGEYSGYDT<u>SGVEL</u> (SEQ ID NO:14)	LQDSNYPLT (SEQ ID NO:18)
JT182	0.5-1nM	TGEYSGYDT<u>PASPD</u> (SEQ ID NO:15)	CS37
SL15	0.1nM	TGEYSGYDT<u>DPQYS</u> (SEQ ID NO:13)	CS37(+L25 A to S)

Residues that differ between the scFv fragments are underlined.

The invention further provides said isolated specific binding member which further comprises a VH CDR1 or VH CDR2 with amino acid sequences substantially as set out as one or both of the VH CDR1 and VH CDR2 of the CS37 VH, preferably both (Table 2).

Table 2: CDR Sequences of CDRs of CS37, SL15 and JT182

Domain	CDR1	CDR2	CDR3
CS37 VH	SYGMH (SEQ ID NO:11)	VISYDGSIKYYADSVKG (SEQ ID NO:12)	TGEYSGYDTSGVEL (SEQ ID NO:14)
SL15 VH	SYGMH (SEQ ID NO:11)	VISYDGSIKYYADSVKG (SEQ ID NO:12)	TGEYSGYDTDPQYS (SEQ ID NO:13)
JT182 VH	SYGMH (SEQ ID NO:11)	VISYDGSIKYYADSVKG (SEQ ID NO:12)	TGEYSGYDTPASPD (SEQ ID NO:15)
CS37 VL	RASQGIGDDLG (SEQ ID NO:16)	GTSTLQS (SEQ ID NO:17)	LQDSNYPLT (SEQ ID NO:18)
SL15S VL	RSSQGIGDDLG (SEQ ID NO:19)	GTSTLQS (SEQ ID NO:17)	LQDSNYPLT (SEQ ID NO:18)

In a preferred embodiment, the binding domains are carried by a human antibody framework. One preferred example of such an embodiment is a VH domain with an amino acid sequence substantially as set out as the JT182 VH domain of which the sequence is set out in SEQ ID NO:10. A further preferred embodiment is a VH domain with an amino acid sequence substantially as set out as the SL15 VH domain, of which the sequence is set out in SEQ ID NO:4.

In a second aspect, the invention provides an isolated specific binding member capable of binding TGFβ_1, wherein said specific binding member comprises an antigen binding domain comprising a VL domain with an amino acid sequence substantially as set out as the SL15S VL domain, of which the sequence is set out in SEQ ID NO:8.

In a further aspect, the invention provides a specific binding

member capable of binding TGFβ_1, comprising a VH domain as set out above with respect to the first aspect, and a VL domain, preferably wherein the VL domain has an amino acid sequence substantially as set out as the CS37 VL (SL15A), of which the

5   sequence is set out in SEQ ID NO:6, or the SL15S VL, of which the sequence is set out in SEQ ID NO:8.

In a particularly preferred embodiment, the invention provides a specific binding member comprising the CS37 VL domain and a VH

10   domain selected from JT182 VH and SL15 VH, most preferably SL15 VH. In a further particularly preferred embodiment, the invention provides a specific binding member comprising SL15 VH and SL15A VL (CS37 VL) or SL15S VL.

15   Preferred embodiments of the present invention provide specific binding members comprising the JT182 VH or SL15 VH domain in which 1, 2, 3, 4 or 5 amino acid substitutions have been made in a CDR, e.g. CDR3, and/or FR, which specific binding members retain ability to bind TGFβ_1. Further preferred embodiments provide

20   specific binding members comprising the SL15A (CS37) VL or SL15S VL, or SL15A or SL15S VL domain in which 1, 2, 3, 4 or 5 amino acid substitutions have been made in a CDR, e.g. CDR3, and/or FR which specific binding members retain ability to bind TGFβ_1. Such amino acid substitutions are generally "conservative", for

25   instance substitution of one hydrophobic residue such as isoleucine, valine, leucine or methionine for another, or the substitution of one polar residue for another, such as arginine for lysine, glutamic for aspartic acid, or glutamine for asparagine. At certain positions non-conservative substitutions

30   are allowable.

Such specific binding members are able to bind TGFβ_1. Preferred

embodiments lack significant cross-reactivity with TGFβ$_2$ and/or TGFβ$_3$, preferably TGFβ$_2$ and TGFβ$_3$.

Preferred embodiments strongly neutralise TGFβ$_1$, having a potency of at least 5 times better than does CS37, more preferably about 10 times, 15 times, 20 times, 50 times, 75 times, 100 times or 150 times better, in a radioreceptor assay (Lucas C et al (1991) *Meth in Enzymology* **198**, 303-16). Potency is measured with the antibody under study and CS37 in equivalent molecular formats, e.g. as monovalent antibodies (scFv or Fab) or as bivalent antibodies (IgG1 or IgG4).

Preferred embodiments bind active TGFβ$_1$ preferentially to latent TGFβ$_1$.

Variants of the VH and VL domains and CDRs of which the sequences are set out herein and which can be employed in specific binding members for TGFβ$_1$ can be obtained by means of methods of sequence alteration or mutation and screening. Such methods are also provided by the present invention.

In addition to antibody sequences, the specific binding member may comprise other amino acids, e.g. forming a peptide or polypeptide, such as a folded domain, or to impart to the molecule another functional characteristic in addition to ability to bind antigen. Specific binding members of the invention may carry a detectable label, or may be conjugated to a toxin or enzyme (e.g. via a peptidyl bond or linker).

In further aspects, the invention provides an isolated nucleic acid which comprises a sequence encoding a specific binding member as defined above, and methods of preparing specific binding

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members of the invention which comprise expressing said nucleic acids under conditions to bring about expression of said binding member, and recovering the binding member.

5   Specific binding members according to the invention may be used in a method of treatment or diagnosis of the human or animal body, such as a method of treatment (which may include prophylactic treatment) of a disease or disorder in a human patient which comprises administering to said patient an effective amount of a

10   specific binding member of the invention. Conditions treatable in accordance with the present invention are described below.

These and other aspects of the invention are described in further detail below.

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All documents mentioned herein are incorporated by reference. Sequences described herein are shown and referred to in the conventional 5' to 3' and N to C terminal notation for nucleic acid and amino acids sequences respectively, unless specifically

20   indicated otherwise.

Brief Description of The Figures.

Figure 1: Neutralisation of TGFβ$_1$ but not TGFβ$_2$ or β$_3$ by SL15S scFv in a proliferation assay using TF1 cells. The neutralisation by

25   Genzyme mAb (Mab 1D.11.16 - squares) or SL15S scFv (diamonds) of TGFβ$_1$, β$_2$ or β$_3$-induced inhibition of proliferation of TF1 is shown.

Figure 2: Inhibition of [^{125}I]TGFβ$_1$ binding to A549 cells by

30   anti-TGFβ$_1$ scFv. ScFv preparations of SL15S, JT183 and CS37 were titrated 2-fold and tested for their ability to inhibit [^{125}I]TGFβ$_1$ binding to A549 cells. SL15S and JT182 were used as his-preps,

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CS37 was fplc-purified.

Figure 3: Inhibition of $[^{125}I]$TGFβ_1 binding to A549 cells by anti-TGFβ_1 antibodies. SL15S scFv, SL15S IgG4 and SL15A IgG4 were compared with Genzyme mAb in their ability to inhibit $[^{125}I]$TGFβ_1 binding to A549 cells. Data are the average of 3 experiments, using a three-fold dilution series.

Figure 4: Inhibition of $[^{125}I]$TGFβ_1 binding to A549 cells by scFv in the presence of latent TGFβ_1. SL15S scFv and SL15A IgG4 were tested for their ability to inhibit $[^{125}I]$TGFβ_1 binding to A549 cells. To investigate whether SL15S recognised latent TGFβ_1, the standard experiment was performed in the presence of 0.1nM latent TGFβ_1, active TGFβ_1 or acid-activated latent TGFβ_1. Data are expressed as % max for each set of conditions.

Figure 5: Neutralisation of TGFβ_1-induced inhibition of TF1 cell proliferation by scFv and IgG in the presence of latent TGFβ_1. The ability of SL15S scFv and SL15A IgG4 to neutralise the growth inhibition induced by latent TGFβ_1, active TGFβ_1 or acid-activated TGFβ_1 was compared in the TF1 assay. In (a) varying concentrations of TGFβ_1 formats were compared where as in (b) scFv and IgG were compared against 20pM TGFβ_1 formats. Data expressed as % control (growth in the absence of TGFβ_1). The inhibition induced by latent TGFβ_1 is due to the small amount of active TGFβ_1 present in the latent preparation.

Figure 6: Inhibition of binding of CS37 scFv displayed on phage to TGFβ_1 using chimaeric TGFβs. Binding of CS37 scFv displayed on phage to TGFβ_1 was assayed by ELISA in the presence of: the TGFβ_1 isoform (TGFβ_1); the TGFβ_2 isoform (TGFβ_2); TGFβ_1/β_2 (83-112) (1-1-2); TGFβ_2/β_1 83-112 (2-2-1); TGFβ_1-β_2 (40-112) (1-2-2); or

$TGF\beta_1$-β_2(92-98) (92-98).

Figure 7: Inhibition of binding of SL15S (Kylie scFv) displayed on phage to $TGF\beta_1$ using chimaeric TGFβs. Binding of SL15S (Kylie) scFv displayed on phage to $TGF\beta_1$ was assayed by ELISA in the presence of: the $TGF\beta_1$ isoform ($TGF\beta_1$); the $TGF\beta_2$ isoform ($TGF\beta_2$); $TGF\beta_1$/β_2 (83-112) (1-1-2); $TGF\beta_2$/β1 83-112 (2-2-1); $TGF\beta_1$-β_2 (40-112) (1-2-2); or $TGF\beta_1$-β_2(92-98) (92-98).

Figure 8: The effect of CAT192 on corneal re-epithelialisation was investigated following an excisional trephine wound of bovine isolated cornea in the air interface organ culture model. Bovine cornea were treated with $100\mu l$ of either serum free Medium 199 (control) or medium containing vehicle (for antibody and $TGF\beta_1$). Null isotype-matched antibody ($10\mu g$), $TGF\beta_1$ (1ng) or CAT192 ($10\mu g$) were administered immediately after wounding and at 12h intervals thereafter. CAT192 caused a significant increase in rate of re-epithelialisation of wounded bovine cornea whereas $TGF\beta_1$ caused a significant decrease in this variable. Data are expressed as percentage re-epithelialisation of the corneal wound. Each point represents the mean value and the vertical bars show s.e.mean of 8 cornea per point. The effect of the different treatments were compared at each time point using repeated measures ANOVA with Bonferroni test. *$P < 0.01$ compared to the null antibody treatment group; t $P < 0.01$ compared to the vehicle treated group.

Figure 9: The effect of CAT192 on corneal re-epithelialisation was investigated following an excisional trephine wound of bovine isolated cornea in the air interface organ culture model. CAT192 (0.001-$10\mu g$) was administered immediately after wounding and at 12h intervals thereafter. CAT192 caused a significant dose-related increase in re-epithelialisation of wounded bovine cornea. The

EC50 for CAT192 was between 0.01 and 0.1μg. Data are expressed as the percentage change in re-epithelialisation of the vehicle treated control group. The dotted lines show the s.e. mean values of the vehicle control group. Each point represents the mean value and the vertical bars show s.e.mean of 6 cornea per point. The effect of the different doses of CAT192 were compared to control treatment using one way ANOVA and Dunnett's test; *P < 0.01.

Detailed Description of the Invention.

TERMINOLOGY

Specific binding member

This describes a member of a pair of molecules which have binding specificity for one another. The members of a specific binding pair may be naturally derived or wholly or partially synthetically produced. One member of the pair of molecules has an area on its surface, or a cavity, which specifically binds to and is therefore complementary to a particular spatial and polar organisation of the other member of the pair of molecules. Thus the members of the pair have the property of binding specifically to each other. Examples of types of specific binding pairs are antigen-antibody, biotin-avidin, hormone-hormone receptor, receptor-ligand, enzyme-substrate. This application is concerned with antigen-antibody type reactions.

Antibody

This describes an immunoglobulin whether natural or partly or wholly synthetically produced. The term also covers any polypeptide or protein having a binding domain which is, or is substantially homologous to, an antibody binding domain. These can be derived from natural sources, or they may be partly or

wholly synthetically produced. Examples of antibodies are the immunoglobulin isotypes and their isotypic subclasses; fragments which comprise an antigen binding domain such as Fab, scFv, Fv, dAb, Fd; and diabodies.

It is possible to take monoclonal and other antibodies and use techniques of recombinant DNA technology to produce other antibodies or chimeric molecules which retain the specificity of the original antibody. Such techniques may involve introducing DNA encoding the immunoglobulin variable region, or the complementarity determining regions (CDRs), of an antibody to the constant regions, or constant regions plus framework regions, of a different immunoglobulin. See, for instance, EP-A-184187, GB 2188638A or EP-A-239400. A hybridoma or other cell producing an antibody may be subject to genetic mutation or other changes, which may or may not alter the binding specificity of antibodies produced.

As antibodies can be modified in a number of ways, the term "antibody" should be construed as covering any specific binding member or substance having a binding domain with the required specificity. Thus, this term covers antibody fragments, derivatives, functional equivalents and homologues of antibodies, including any polypeptide comprising an immunoglobulin binding domain, whether natural or wholly or partially synthetic. Chimeric molecules comprising an immunoglobulin binding domain, or equivalent, fused to another polypeptide are therefore included. Cloning and expression of chimeric antibodies are described in EP-A-0120694 and EP-A-0125023.

It has been shown that fragments of a whole antibody can perform the function of binding antigens. Examples of binding fragments

are (i) the Fab fragment consisting of VL, VH, CL and CH1 domains;
(ii) the Fd fragment consisting of the VH and CH1 domains; (iii)
the Fv fragment consisting of the VL and VH domains of a single
antibody; (iv) the dAb fragment (Ward, E.S. et al., Nature 341,
544-546 (1989)) which consists of a VH domain; (v) isolated CDR
regions; (vi) F(ab')2 fragments, a bivalent fragment comprising
two linked Fab fragments (vii) single chain Fv molecules (scFv),
wherein a VH domain and a VL domain are linked by a peptide linker
which allows the two domains to associate to form an antigen
binding site (Bird et al, Science, **242**, 423-426, 1988; Huston et
al, PNAS USA, **85**, 5879-5883, 1988); (viii) bispecific single chain
Fv dimers (PCT/US92/09965) and (ix) "diabodies", multivalent or
multispecific fragments constructed by gene fusion (WO94/13804;
P. Holliger et al, Proc. Natl. Acad. Sci. USA **90** 6444-6448, 1993).
Fv, scFv or diabody molecules may be stabilised by the
incorporation of disulphide bridges linking the VH and VL domains
(Y. Reiter et al, Nature Biotech, **14**, 1239-1245, 1996).
Minibodies comprising a scFv joined to a CH3 domain may also be
made (S. Hu et al, Cancer Res., **56**, 3055-3061, 1996).

Diabodies are multimers of polypeptides, each polypeptide
comprising a first domain comprising a binding region of an
immunoglobulin light chain and a second domain comprising a
binding region of an immunoglobulin heavy chain, the two domains
being linked (e.g. by a peptide linker) but unable to associate
with each other to form an antigen binding site: antigen binding
sites are formed by the association of the first domain of one
polypeptide within the multimer with the second domain of another
polypeptide within the multimer (WO94/13804).

Where bispecific antibodies are to be used, these may be
conventional bispecific antibodies, which can be manufactured in

a variety of ways (Holliger, P. and Winter G. Current Opinion
Biotechnol. 4, 446-449 (1993)), e.g. prepared chemically or from
hybrid hybridomas, or may be any of the bispecific antibody
fragments mentioned above. It may be preferable to use scFv
5 dimers or diabodies rather than whole antibodies. Diabodies and
scFv can be constructed without an Fc region, using only variable
domains, potentially reducing the effects of anti-idiotypic
reaction.

10 Bispecific diabodies, as opposed to bispecific whole antibodies,
may also be particularly useful because they can be readily
constructed and expressed in *E.coli*. Diabodies (and many other
polypeptides such as antibody fragments) of appropriate binding
specificities can be readily selected using phage display
15 (WO94/13804) from libraries. If one arm of the diabody is to be
kept constant, for instance, with a specificity directed against
antigen X, then a library can be made where the other arm is
varied and an antibody of appropriate specificity selected.
Bispecific whole antibodies may be made by knobs-into-holes
20 engineering (J. B. B. Ridgeway et al, Protein Eng., 9, 616-621,
1996).

Diabodies may be made with one binding site for $TGF\beta_1$ formed by VH
and VL domains as disclosed in this application and the other
25 binding site being for $TGF\beta_2$. The $TGF\beta_2$ binding site may be
formed for instance from the VH and VL domains of the antibody 6B1
(WO97/13844).

Antigen binding domain
30 This describes the part of an antibody which comprises the area
which specifically binds to and is complementary to part or all
of an antigen. Where an antigen is large, an antibody may only

bind to a particular part of the antigen, which part is termed an epitope. An antigen binding domain may be provided by one or more antibody variable domains (e.g. a so-called Fd antibody fragment consisting of a VH domain). Preferably, an antigen binding domain

5   comprises an antibody light chain variable region (VL) and an antibody heavy chain variable region (VH).

Specific

This may be used to refer to the situation in which one member of

10   a specific binding pair will not show any significant binding to molecules other than its specific binding partner(s). The term is also applicable where e.g. an antigen binding domain is specific for a particular epitope which is carried by a number of antigens, in which case the specific binding member carrying the

15   antigen binding domain will be able to bind to the various antigens carrying the epitope.

Comprise

This is generally used in the sense of include, that is to say

20   permitting the presence of one or more features or components.

Isolated

This refers to the state in which specific binding members of the invention, or nucleic acid encoding such binding members, will be

25   in accordance with the present invention. Members and nucleic acid will be free or substantially free of material with which they are naturally associated such as other polypeptides or nucleic acids with which they are found in their natural environment, or the environment in which they are prepared (e.g.

30   cell culture) when such preparation is by recombinant DNA technology practised *in vitro* or *in vivo*. Members and nucleic acid may be formulated with diluents or adjuvants and still for

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practical purposes be isolated - for example the members will normally be mixed with gelatin or other carriers if used to coat microtitre plates for use in immunoassays, or will be mixed with pharmaceutically acceptable carriers or diluents when used in diagnosis or therapy. Specific binding members may be glycosylated, either naturally or by systems of heterologous eukaryotic cells (e.g. CHO or NSO (ECACC 85110503) cells, or they may be (for example if produced by expression in a prokaryotic cell) unglycosylated.

By "substantially as set out" it is meant that the relevant CDR or VH or VL domain of the invention will be either identical or highly similar to the specified regions of which the sequence is set out herein. By "highly similar" it is contemplated that from 1 to 5, preferably from 1 to 4 such as 1 to 3 or 1 or 2, or 3 or 4, substitutions may be made in the CDR and/or VH or VL domain.

The structure for carrying a CDR of the invention will generally be of an antibody heavy or light chain sequence or substantial portion thereof in which the CDR is located at a location corresponding to the CDR of naturally occurring VH and VL antibody variable domains encoded by rearranged immunoglobulin genes. The structures and locations of immunoglobulin variable domains may be determined by reference to (Kabat, E.A. et al, Sequences of Proteins of Immunological Interest. 4th Edition. US Department of Health and Human Services. 1987, and updates thereof, now available on the Internet (http://immuno.bme.nwu.edu)). CDRs are generally as defined by Kabat. Additionally, in CDR grafting residues of the loop defined by Chothia adjacent the Kabat VH CDR1 may be grafted. For SL15S this would comprise residues 26 to 30 of the heavy chain (GFTGS).

Preferably, an amino acid sequence substantially as set out in Table 1 is carried as the CDR3 in a human heavy chain variable domain or a substantial portion thereof.

5   Variable domains employed in the invention may be derived from any germline or rearranged human variable domain, or may be a synthetic variable domain based on consensus sequences of known human variable domains. CDR-derived sequences of the invention may be introduced into a repertoire of variable domains lacking

10   CDR3 regions, using recombinant DNA technology.

For example, Marks *et al* (*Bio/Technology*, 1992, 10:779-783) describe methods of producing repertoires of antibody variable domains in which consensus primers directed at or adjacent to the

15   5' end of the variable domain area are used in conjunction with consensus primers to the third framework region of human VH genes to provide a repertoire of VH variable domains lacking a CDR3. Marks *et al* further describe how this repertoire may be combined with a CDR3 of a particular antibody. Using analogous techniques,

20   the CDR3-derived sequences of the present invention may be shuffled with repertoires of VH or VL domains lacking a CDR3, and the shuffled complete VH or VL domains combined with a cognate VL or VH domain to provide specific binding members of the invention. The repertoire may then be displayed in a suitable host system

25   such as the phage display system of WO92/01047 so that suitable specific binding members may be selected. A repertoire may consist of from anything from 10^4 individual members upwards, for example from 10^6 to 10^8 or 10^{10} members.

30   Analogous shuffling or combinatorial techniques are also disclosed by Stemmer (*Nature*, 1994, 370:389-391), who describes the technique in relation to a β-lactamase gene but observes that the

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approach may be used for the generation of antibodies.

A further alternative is to generate novel VH or VL regions carrying a CDR-derived sequences of the invention using random mutagenesis of, for example, the SL15 or JT182 VH gene or SL15A or SL15S VL genes to generate mutations within the entire variable domain. Such a technique is described by Gram *et al* (1992, *Proc. Natl. Acad. Sci., USA,* 89:3576-3580), who used error-prone PCR.

Another method which may be used is to direct mutagenesis to CDR regions of VH or VL genes. Such techniques are disclosed by Barbas *et al*, (1994, *Proc. Natl. Acad. Sci., USA,* 91:3809-3813) and Schier *et al* (1996, *J. Mol. Biol.* 263:551-567).

All the above described techniques are known as such in the art and in themselves do not form part of the present invention. The skilled person will be able to use such techniques to provide specific binding members of the invention using routine methodology in the art.

A further aspect of the invention provides a method for obtaining an antibody antigen binding domain specific for TGFβ$_1$ and preferably one or more of the additional properties disclosed herein for specific binding members according to embodiments of the invention, the method comprising providing by way of addition, deletion, substitution or insertion of one or more amino acids in the amino acid sequence of a VH domain set out herein (SL15 or JT182) a VH domain which is an amino acid sequence variant of the VH domain, combining the VH domain thus provided with one or more VL domains, and testing the VH/VL combination or combinations to identify an antibody antigen binding domain specific for TGFβ$_1$ and optionally with one or more of said preferred properties. Said

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VL domain may have an amino acid sequence which is substantially as set out for SL15A VL (CS37) or may have an amino acid sequence which is substantially as set out for VL.

5   An analogous method may be employed in which one or more sequence variants of a VL domain disclosed herein are combined with one or more VH domains.

A further aspect of the invention provides a method of preparing
10   a specific binding member specific for TGFβ$_1$, which method comprises:

a)   providing a starting repertoire of nucleic acids encoding a VH domain which either include a CDR3 to be replaced or lack a CDR3 encoding region;

15   b)   combining said repertoire with a donor nucleic acid encoding an amino acid sequence substantially as set out herein for SL15 or JT182 VH CDR3 such that said donor nucleic acid is inserted into the CDR3 region in the repertoire, so as to provide a product repertoire of nucleic acids encoding a VH domain;

20   c)   expressing the nucleic acids of said product repertoire; and

d)   selecting a specific binding member specific for TGFβ$_1$; and

e)   recovering said specific binding member or nucleic acid encoding it.

25   Again, an analogous method may be employed in which a VL CDR3 of the invention is combined with a repertoire of nucleic acids encoding a VL domain which either include a CDR3 to be replaced or lack a CDR3 encoding region.

30   Similarly, one or more, or all three CDRs may be grafted into a repertoire of VH or VL domains which are then screened for a specific binding member or specific binding members specific for

$TGF\beta_1$.

A substantial portion of an immunoglobulin variable domain will comprise at least the three CDR regions, together with their intervening framework regions. Preferably, the portion will also include at least about 50% of either or both of the first and fourth framework regions, the 50% being the C-terminal 50% of the first framework region and the N-terminal 50% of the fourth framework region. Additional residues at the N-terminal or C-terminal end of the substantial part of the variable domain may be those not normally associated with naturally occurring variable domain regions. For example, construction of specific binding members of the present invention made by recombinant DNA techniques may result in the introduction of - or C-terminal residues encoded by linkers introduced to facilitate cloning or other manipulation steps. Other manipulation steps include the introduction of linkers to join variable domains of the invention to further protein sequences including immunoglobulin heavy chains, other variable domains (for example in the production of diabodies) or protein labels as discussed in more details below.

Although in a preferred aspect of the invention specific binding members comprising a pair of VH and VL domains are preferred, single binding domains based on either VH or VL domain sequences form further aspects of the invention. It is known that single immunoglobulin domains, especially VH domains, are capable of binding target antigens in a specific manner.

In the case of either of the single chain specific binding domains, these domains may be used to screen for complementary domains capable of forming a two-domain specific binding member able to bind $TGF\beta_1$.

This may be achieved by phage display screening methods using the so-called hierarchical dual combinatorial approach as disclosed in WO 92/01047 in which an individual colony containing either an H or L chain clone is used to infect a complete library of clones encoding the other chain (L or H) and the resulting two-chain specific binding member is selected in accordance with phage display techniques such as those described in that reference. This technique is also disclosed in Marks *et al, ibid.*

Specific binding members of the present invention may further comprise antibody constant regions or parts thereof. For example, a VL domain such as SL15A VL or SL15S VL may be attached at their C-terminal end to antibody light chain constant domains including human Cκ or Cλ chains, preferably Cλ chains. Similarly, specific binding members based on SL15 VH may be attached at their C-terminal end to all or part of an immunoglobulin heavy chain derived from any antibody isotype, e.g. IgG, IgA, IgE and IgM and any of the isotype sub-classes, particularly IgG1 and IgG4. IgG4 is preferred.

Antibodies of the invention may be labelled with a detectable or functional label. Detectable labels include radiolabels such as ^{131}I or ^{99}Tc, which may be attached to antibodies of the invention using conventional chemistry known in the art of antibody imaging. Labels also include enzyme labels such as horseradish peroxidase. Labels further include chemical moieties such as biotin which may be detected via binding to a specific cognate detectable moiety, e.g. labelled avidin.

Antibodies of the present invention are designed to be used in methods of diagnosis or treatment in human or animal subjects, preferably human.

Antibodies specific for human TGFβ_1 have been shown to be effective in animal models for the treatment of fibrotic diseases and other diseases where TGFβ_1 is overexpressed such as rheumatoid arthritis or cancer. Antibodies against TGFβ_1 have been shown to be effective in the treatment of glomerulonephritis (W.A. Border et al Nature 346 371-374, 1990); neural scarring (A. Logan et al Eur. J. Neurosci. 6 355-363, 1994); dermal scarring (M. Shah et al Lancet 339 213-214, 1992; M. Shah et al J. Cell. Science 107 1137-1157,1994; M. Shah et al 108 985-1002, 1995), and pulmonary fibrosis (Giri et al Thorax 48, 959-966, 1993). Further, antibodies cross-reactive with the isoforms, TGFβs 1,2 and 3, have been shown to be effective in models of lung fibrosis, radiation induced fibrosis (Barcellos-Hoff, US Patent 5616561 (1997)), myelofibrosis, burns, Dupuyen's contracture, gastric ulcers and rheumatoid arthritis (Wahl et al J. Exp. Medicine 177 225-230, 1993).

There are a number of further conditions associated with extracellular matrix deposition that may be ameliorated by administration of an antibody directed to TGFβ_1. These include systemic sclerosis, postoperative adhesions, keloid and hypertrophic scarring, proliferative vitreoretinopathy, glaucoma drainage surgery, corneal injury, cataract, Peyronie's disease, diabetic nephropathy, adult respiratory distress syndrome, cirrhosis of the liver, post myocardial infarction, post angioplasty restenosis, keloid scars, scarring after subarachnoid haemorrhage, multiple sclerosis, fibrosis after laminectomy, fibrosis after tendon and other repairs, tatoo removal, sclerosing cholangitis, pericarditis, pleurisy, tracheostomy, penetrating CNS injury, eosinophilic myalgic syndrome, vascular restenosis, veno-occlusive disease, pancreatitis and psoriatic arthropathy. In some cases treatment in combination with an antibody directed

against $TGF\beta_2$, such as 6B1 IgG4 (CAT-152) (see WO97/13844) may be valuably employed, for instance in the treatment of dermal scarring. The efficacy of SL15A IgG4 in treatment of corneal epithelial wound healing is demonstrated in Example 6.

The success of CAT-192 in promoting corneal wound healing provides indication of its usefulness in other conditions where promotion of re-epithelialisation is beneficial. These include diseases of the skin, such as venous ulcers, ischaemic ulcers (pressure sores), diabetic ulcers, graft sites, graft donor sites, abrasions and burns, diseases of the bronchial epithelium, such as asthma, ARDS, diseases of the intestinal epithelium, such as mucositis associated with cytotoxic treatment, oesophagual ulcers (reflex disease), stomach ulcers, small intestinal and large intestinal lesions (inflammatory bowel disease).

$TGF\beta$ also inhibits endothelial proliferation so anti-$TGF\beta$ antibodies may be used to stabilise atherosclerotic plaques and speed healing of vascular anastomoses. $TGF\beta$ may stimulate smooth muscle proliferation so anti-$TGF\beta$ treatment may be additionally appropriate or arterial disease and for asthma.

Asthma is a chronic inflammatory disorder of the airways manifesting as intermittent airflow obstruction, which over time may become progressive. Both in the allergic and non-allergic forms of the disease, there is evidence of an altered local T cell response in favour of the Th-2 cytokine release resulting on B-cell isotype switching to IgE, mast cell, eosinophil and basophil recruitment and activation and release of a wide range of inflammatory mediators. However, it has become clear that by itself, inflammation is not able to explain many of the features characteristic of chronic asthma and that restructuring of airway

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wall is also required (Holgate ST et al., *J. Allergy Clin. Immunol.* 2000 (in press)). This "remodelling" response accounts for the incomplete therapeutic efficacy of corticosteroids, with persistent bronchial hyperresponsiveness (BHR) (Lundgren R et al., (1988) *Eur. Respir. J.* 1(10), 883-889), and the progressive decline in pulmonary function over time, which occurs in those asthmatics with more chronic and severe disease (Lange P et al., (1998) *N. Engl. J. Med.* 339(17), 1194-1200).

Subepithelial and submucosal fibrosis is implicated in asthma. When assessed by high resolution CT, patients with severe asthma have thicker airways when compared to normal subjects or those with mild disease (Awadh N et al., (1998) *Thorax* 53(4), 248-253). This involves thickening and increased density of the SBM collagen layer, increases in smooth muscle and microvascular networks (Carroll N et al., (1993) *Am. Rev. Respir. Dis.* 147(2), 405-410). On the basis of measurements made in human airways and in a guinea pig model of chronic antigen exposure, SBM thickening reflects that of the entire airway wall. SBM-collagen thickness has been shown to correlate with disease severity, chronicity and BHR.

SBM thickening is due to the deposition of interstitial collagens Types I, III and V and fibronectin in the *lamina reticularis* and originates from the myofibroblasts whose numbers and activity are increased in asthma (Brewster CE et al., (1990) *Am. J. Respir. Cell Mol. Biol.* 3(5), 507-511) and further enhanced by allergen exposure (Gizycki MJ et al., (1997) *Am. J. Respir. Cell Mol. Biol.* 16(6), 664-673). Bronchial biopsy and lavage studies have provided a compelling case for the epithelium as a potential source of profibrogenic growth factors. In asthma, immunostaining for TGFβ and b-FGF show both epithelial localisation and extensive staining of matrix, indicative of important interactions between

these growth factors and matrix proteoglycans through specific glycosaminoglycan (GAG) binding sites (Redington AE et al., (1998) *J. Pathol.* 186(4), 410-415). Both $TGF\beta_1$ and b-FGF are found in increased concentrations in lavage fluid, with further increases occurring after allergen exposure (Redington AE et al., (1997) *Am. J. Respir. Crit. Care Med.* 156(2, Pt 1), 642-647). Tissue analysis of growth factors, cytokines and chemokines have shown that these are mainly present in complex, high molecular weight forms. Latency associated peptide has been identified as the $TGF\beta$ binding molecule and using a bronchial explant model, it has been shown that allergen exposure of asthmatic mucosal tissue results in activation of $TGF\beta$ that is dependant upon plasmin activity, while b-FGF is released in soluble form by heparin and heparinase from mast cells and eosinophils respectively (McConnell W et al., *Eur. Respir. J.* 152s. 1999, Ref Type: Abstract).

Asthma is also involved in epithelial injury and airways remodelling. A characteristic feature of the remodelled airways in asthma is extensive epithelial damage caused by inflammatory cell products (Laitinen LA et al., (1985) *Am. Rev. Respir. Dis.* 131(4), 599-606). Mucosal damage not only allows tissue damaging molecules to pass unimpeded into the airways wall, but also causes the epithelium to become "activated" with expression of a variety of proinflammatory chemokines, autacoid mediators and adhesion molecules which contribute to chronic inflammation (Holgate ST et al., *J. Allergy Clin. Immunol.* 2000 (in press)). Injured and repairing epithelial cells are also important regulators of airway remodelling through increased production of fibroproliferative and profibrogenic growth factors including $TGF\beta$ isoforms (Zhang S et al., (1999) *Lab. Invest.* 79(4), 395-405). It has recently been found that impairment of epidermal growth factor receptor (EGFR)-mediated epithelial repair causes greatly increased release of

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$TGF\beta_2$ by damaged epithelial cells and a marked enhancement of collagen III gene expression when conditioned medium is added to myofibroblast cultures. As TGFβ isoforms are potent inhibitors of epithelial cell proliferation, excessive production of TGFβ in asthma may account for the unexpectedly low level of expression of the proliferation marker PCNA found in asthmatic epithelium (Demoly P et al., (1994) *Am. J. Respir. Crit. Care Med.* 150(1), 214-217). In this way, conditions that favour collagen biosynthesis by the sub-epithelial myofibroblasts, may also contribute to disease chronicity by retarding epithelial repair. Hence reducing TGFβ levels by the use of specific binding members of the present invention would be expected to address the need in chronic and severe asthma to prevent matrix protein biosynthesis by bronchial myofibroblasts, as well as promoting bronchial epithelial repair in order to restore a non-activated epithelial phenotype and normal barrier function.

$TGF\beta_1$ also modulates immune and inflammatory responses, for instance in response to malignancy and infection. An antibody against $TGF\beta_1$ may be used for improving the immune response to infections such as hepatitis B, hepatitis C or tuberculosis or for reducing immunosuppression induced, for instance, by tumours or AIDS infection or granulomatous diseases. An antibody against $TGF\beta_1$ may be useful for treatment of acute and chronic rejection of organ transplant and malignant tumours, and may be used in prevention of the spread of cancer cells induced by treatment with cyclosporine.

An antibody against $TGF\beta_1$ may be used as an adjuvant for immunotherapy.

An antibody against $TGF\beta_1$ may be used for inhibition of

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angiogenesis, for instance in treatment of tumours. The majority of tumour cells express detectable levels of $TGF\beta_1$ (Wojtowicz-Praga 1997, *J. Immunother.* 20 (3): 165-77). Furthermore, cells that produce higher levels of $TGF\beta_1$ have a higher metastatic (Blanckaert et al., 1993, *Cancer. Res.* 53 (17); 4075-81) or invasive (Arteaga et al., 1993, *Cell Growth and Differentiation* 4 (3): 193-201) potential. In many cancers $TGF\beta_1$ plasma levels are correlated with disease progression. Thus the source of $TGF\beta_1$ can be the tumour cells as well as surrounding tissue.

$TGF\beta$ is a potent suppressor of malignant transformation in normal healthy epithelial tissue and can inhibit proliferation. However, many advanced cancers become resistant to the growth-inhibitory actions of $TGF\beta$ as a result of abnormalities in the type II $TGF\beta$ receptor (Markowitz et al., 1995, *Science* 268 (5215): 1336-8) or SMAD signal transduction (Hata et al., 1998, *Mol. Med. Today* 4 (6): 257-62).

Tumours require a blood supply for growth in excess of $1mm^3$ and for metastasis (Folkman 1995, *Breast Cancer Res. Treat.* 36 (2): 109-18). This has led to the rapid development of anti-angiogenic treatments for solid tumours.

$TGF\beta_1$ has been shown to cause angiogenesis indirectly by up regulating VEGF production in vitro and in vivo. Breast cancers contain large numbers of infiltrating macrophages. The role and function of these cells within the tumour remain unclear, but a number of studies have found an association with poor prognosis. Both tumour cells and tumour macrophages produce VEGF in vitro and production is up regulated by $TGF\beta_1$. Serum VEGF level is enhanced in patients with breast cancer and these levels directly correlate to serum $TGF\beta_1$ levels. Thus, $TGF\beta_1$ expression by breast cancer

cells and cancer-associated macrophages may elect an angiogenic response through generation of VEGF (Donovan et al., 1997, *Ann. Surg. Oncol.* 4 (8): 621.7; Harmey et al., 1998, *Ann. Surg. Oncol.* 5(3): 271-8).

5

Ueki et al. (1992, *Japanese Journal of Cancer Research* 84(6): 589-93) demonstrated that $TGF\beta_1$ enhanced tumour growth in vivo. This group transected CHO cells with the $TGF\beta_1$ gene resulting in overexpression of $TGF\beta_1$. $TGF\beta_1$-secreting CHO cells were shown to

10   grow more rapidly that non-transected cells when injected subcutaneously into nude mice. Prominent vascularisation was observed in tumours derived from $TGF\beta_1$-transected cells; vascularisation was diminished in the non-transected cells. In addition, an anti-$TGF\beta_1$ neutralising antibody was able to inhibit

15   both growth and angiogenesis in the tumours derived from $TGF\beta_1$-transected cells. Thus, overproduction of $TGF\beta_1$ by tumour cells contributed to tumour growth and neovascularisation.

It is known that patients who have cancer also have a defective

20   immune system. Recently $TGF\beta_1$ has been suggested to play a key role in tumour-associated immunosuppression. This topic has been the focus of a recent review (Wojtowicz-Praga, 1997, *ibid*). Certainly, $TGF\beta_1$ appears to be a potent immunosuppressor, and it has been consistently detected from a variety of tumour cell lines

25   and in plasma of tumour-bearing hosts.

Neutralisation of $TGF\beta_1$ by monoclonal antibodies or inhibition of production by antisense results in attenuation of tumour growth and metastatic ability in animal models. Growth of MCF-7 breast

30   cancer cells transected with $TGF\beta_1$ in mice is prevented with 2G7 (repeated i.p. does), an anti-$TGF\beta_{1\ 2\ 3}$ antibody (Arteaga et al., *ibid*). Growth of normal MCF-7 cells is prevented by 2G7 but only

when treatment started at the time of tumour cell inoculation.
Further, more convincing evidence for an action of anti-TGFβ
antibodies to relive tumour-induced immunosuppression has been
provided (Arteaga et al., *J. Clin. Invest.* 92 (6): 2569-76). MDA-
231, a human breast cancer cells line caused a decrease in spleen
natural killer (NK) cell activity in nude mice following i.p.
inoculation. 2G7 (200μg every 2 days, i.p.) attenuated intra-
abdominal tumours and lung metastasis as well as markedly
increasing the activity of spleen NK cell activity. Furthermore,
conditioned medium from cultures of MDA-231 tumour cells inhibited
the NK cell activity of human blood; again 2G7 prevented this.
Growth of subcutaneous xenografts of MDA-231 cells were only
transient inhibited by 2G7. The action of 2G7 on tumour growth,
metastasis, and NK cell activity were absent in beige NK cell-
deficient nude mice (Arteaga et al., *J. Clin. Invest.* 92 (6):
2569-76).

In a further study, the 2G7 anti-TGFβ antibody (500μg i.p. every
other day) in combination with IL-2 (10000U i.p. 2x daily) was
able to reduce B16 melanoma lung metastasis but was not as
effective i.v. inoculation. 2G7 alone also reduced the number of
lung metastasis but was not as effective as the combined therapy.
Plasma TGFβ$_1$ levels were significantly reduced in the antibody
treated animals (Wojtowicz-Praga et al., 1996, *J. Immunother.
Emphasis Tumour Immunol.* 19(3): 169-75). Two previous studies
either failed to show an effect or only caused a small effect
using the combination of anti-TGFβ$_1$ and IL-2 (Gridley et al.,
1993, *Cancer Biother.* 8 (2); 159-70; Mao et al, 1994, *Cancer
Biother.* 9(4): 317-27, respectively), however, the doses of anti-
TGFβ$_1$ antibodies used in these studies were small (100ng and 1μg
respectively). Thus, combination of anti-TGFβ therapy with
immunostimulation would appear, from animal model data, to provide

proof of concept for this therapeutic approach to cancer.

Hoefer and Anderer (1995, *Cancer Immunol. Immunother.* 41 (5): 302-
8) demonstrated that the human carcinoma cell line, SLU-1, and the
highly metastatic sub-line SLU-M1, resulted in metastasis in nude
mice following s.c. inoculation. The incidence of metastasis as
well as primary tumour growth was reduced by treatment with anti-
TGFβ_1 antibodies (treatment from day 3, every 3-4 days with 100μg
s.c. at the tumour site). The authors suggested that the
antibodies reversed TGFβ_1-induced immunosuppression leading to
inhibition of tumour growth and metastasis.

Previous work has also demonstrated that anti-TGFβ antibodies can
reduce tumour metastasis in vivo (Arteaga et al., 1993, *J. Clin.,*
Invest. 92(6): 2569-76; Hoefer & Anderer, 1995, *ibid*; Wojtowicz-
Praga et al., 1996, *ibid*). Initial conclusions from these studies
suggested that TGFβ_1-induced immunosuppression permitted
metastasis of these tumour xenografts. However, a recent paper
suggests that TGFβ_1 may enhance the invasive and metastatic
potential of cells directly (Hojo et al., 1999, *Nature* 397: 530-
534). Cyclosporin dose-dependently induces TGFβ_1 release from
human pulmonary adenocarcinoma cells in culture, however, the
mechanism of TGFβ production by cyclosporin is not known.
Treatment of adenocarcinoma cells with cyclosporin (or TGFβ_1)
results in membrane ruffling, pseudopodia formation, anchorage-
independent (invasive) growth and motility. An anti-TGFβ_1
antibody inhibits these cell morphology and motility changes in
vitro. Similar observations were made for renal cells
adenocarcinoma, mammary gland epithelial cells and mink lung
epithelial lung cells. In immunodeficient SCID-beige mice
(deficient in T cells, B cells, NK cells), cyclosporin increased
the number of metastasis following incubation (i.v.) Of murine

renal cell adenocarcinoma, Lewis lung carcinoma or human bladder cancer cells. Treatment with the anti-TGF$\beta_{1\ 2\ 3}$ neutralising antibody, 1D11.16 (200μg per day, initial dose 1 day prior to tumour cell inoculation) significantly reduced the number of

5   pulmonary metastasis in cyclosporin treated mice (to levels below that of the non-cyclosporin treated control group). Thus, it appears and in that cyclosporin can, through an action dependant on TGFβ_1 production, increase invasion and metastasis in animal models independent of the host's immune system (Hojo et al., 1999,

10   *ibid*).

Evidence from in vitro and in vivo models suggests that TGFβ_1, can enhance tumour formation utilising three main mechanisms; angiogenesis, immunosuppression and phenotypic changes of tumour

15   cells to increase invasive and metastatic behaviour. Thus, inhibition of TGFβ_1 would be expected to inhibit malignancy in man and within a single molecule, deliver a combined anti-cancer therapy.

20   Cancers in which TGFβ_1 have been implicated include breast, prostate, ovarian, stomach, colerectal, skin, lung, cervical and bladder cancers, as well as various leukemias and sarcomas, such as Kaposi's Sarcoma. Accordingly, antibodies of the invention may be administered for the treatment of cancers in which TGFβ_1 is

25   implicated either angiogensis, metastasis or tumour progression, including cancers of the foregoing conditions. It will of course be appreciated that in the context of cancer therapy, "treatment" includes any medical intervention resulting in the slowing of tumour growth or reduction in tumour metastases, as well as

30   partial remission of the cancer in order to prolong life expectancy of a patient.

Antibody therapy for the treatment of cancer is an established
treatment in the art. Three anti-cancer antibodies are currently
licenced for clinical use in the US and/or Europe (Panorex for the
treatment of colorectal cancer, Rituxan for B-cell lymphoma and
Herceptin for breast cancer), in addition to numerous other anti-
cancer antibodies currently in Phase I, II or III clinical trials.
These antibodies are often used in late stage treatment and are
considered effective by the criteria of the preceding paragraph,
as well as, in some cases, providing complete remission of the
tumour.

Accordingly, further aspects of the invention provide methods of
treatment comprising administration of a specific binding member
as provided, pharmaceutical compositions comprising such a
specific binding member, and use of such a specific binding member
in the manufacture of a medicament for administration, for example
in a method of making a medicament or pharmaceutical composition
comprising formulating the specific binding member with a
pharmaceutically acceptable excipient.

In accordance with the present invention, compositions provided
may be administered to individuals. Administration is preferably
in a "therapeutically effective amount", this being sufficient to
show benefit to a patient. Such benefit may be at least
amelioration of at least one symptom. The actual amount
administered, and rate and time-course of administration, will
depend on the nature and severity of what is being treated.
Prescription of treatment, eg decisions on dosage etc, is within
the responsibility of general practioners and other medical
doctors. Appropriate doses of antibody are well known in the art;
see Ledermann J.A. et al. (1991) Int J. Cancer 47: 659-664;
Bagshawe K.D. et al. (1991) Antibody, Immunoconjugates and

Radiopharmaceuticals 4: 915-922.

A composition may be administered alone or in combination with other treatments, either simultaneously or sequentially dependent upon the condition to be treated.

Antibodies of the present invention may be administered to a patient in need of treatment via any suitable route, usually by injection into the bloodstream or directly into the site to be treated, e.g. cornea, wound, tumour, etc. The precise dose will depend upon a number of factors, including whether the antibody is for diagnosis or for treatment, the size and location of the area to be treated (e.g. wound), the precise nature of the antibody (e.g. whole antibody, fragment or diabody), and the nature of any detectable label or other molecule attached to the antibody. A typical antibody dose will be in the range 0.5mg to 100g for systemic applications, such as treatment of fibrosis in glomerulonephritis or in the treatment of cancers and 10μg to 1mg for local applications such as treatment of dermal scarring. Typically, the antibody will be a whole antibody, preferably the IgG4 isotype. This is a dose for a single treatment of an adult patient, which may be proportionally adjusted for children and infants, and also adjusted for other antibody formats in proportion to molecular weight. Treatments may be repeated at daily, twice-weekly, weekly or monthly intervals, at the discretion of the physician.

It is presently preferred that a whole antibody of the IgG4 isotype is used for systemic and local applications but for local applications a scFv antibody may be particularly valuable.

Specific binding members of the present invention will usually be

administered in the form of a pharmaceutical composition, which may comprise at least one component in addition to the specific binding member.

5   Thus pharmaceutical compositions according to the present invention, and for use in accordance with the present invention, may comprise, in addition to active ingredient, a pharmaceutically acceptable excipient, carrier, buffer, stabiliser or other materials well known to those skilled in the art. Such materials

10   should be non-toxic and should not interfere with the efficacy of the active ingredient. The precise nature of the carrier or other material will depend on the route of administration, which may be oral, or by injection, e.g. intravenous.

15   Pharmaceutical compositions for oral administration may be in tablet, capsule, powder or liquid form. A tablet may comprise a solid carrier such as gelatin or an adjuvant. Liquid pharmaceutical compositions generally comprise a liquid carrier such as water, petroleum, animal or vegetable oils, mineral oil

20   or synthetic oil. Physiological saline solution, dextrose or other saccharide solution or glycols such as ethylene glycol, propylene glycol or polyethylene glycol may be included. Formulation as eye drops may be valuable for prevention or treatment of ocular fibrosis or scarring.

25

For intravenous, injection, or injection at the site of affliction, the active ingredient will be in the form of a parenterally acceptable aqueous solution which is pyrogen-free and has suitable pH, isotonicity and stability. Those of relevant

30   skill in the art are well able to prepare suitable solutions using, for example, isotonic vehicles such as Sodium Chloride Injection, Ringer's Injection, Lactated Ringer's Injection.

Preservatives, stabilisers, buffers, antioxidants and/or other additives may be included, as required.

The antibody may be administered from a sustained delivery system to prevent fibrosis or may be coated onto prosthetic devices, such as hip replacements, to prevent development of fibrosis associated with their insertion.

A composition may be administered alone or in combination with other treatments, either simultaneously or sequentially dependent upon the condition to be treated. Other treatments may include the administration of suitable doses of pain relief drugs such as non-steroidal anti-inflammatory drugs (e.g. asprin, paracetamol, ibuprofen or ketoprofen) or opitates such as morphine, or anti-emetics.

The present invention provides a method comprising causing or allowing binding of a specific binding member as provided herein to TGFβ_1. As noted, such binding may take place *in vivo*, e.g. following administration of a specific binding member, or nucleic acid encoding a specific binding member, or it may take place *in vitro*.

The amount of binding of specific binding member to TGFβ_1 may be determined. Quantitation may be related to the amount of TGFβ_1 in a test sample, which may be of diagnostic interest, which may be of diagnostic interest, for example, measurement of TGFβ_1 has also been proposed as an indicator for atherosclerosis, low concentrations being correlated with advanced atherosclerosis.

The reactivities of antibodies on a sample may be determined by any appropriate means. Radioimmunoassay (RIA) is one possibility.

Radioactive labelled $TGF\beta_1$ is mixed with unlabelled $TGF\beta_1$ (the test sample) and allowed to bind to the antibody. Bound $TGF\beta_1$ is physically separated from unbound $TGF\beta_1$ and the amount of radioactive $TGF\beta_1$ bound to the antibody determined. The more $TGF\beta_1$ there is in the test sample the less radioactive $TGF\beta_1$ will bind to the antibody. A competitive binding assay may also be used with non-radioactive $TGF\beta_1$, using $TGF\beta_1$ or an analogue of $TGF\beta_1$ linked to a reporter molecule. The reporter molecule may be a fluorochrome, phosphor or laser dye with spectrally isolated absorption or emission characteristics. Suitable fluorochromes include fluorescein, rhodamine, phycoerythrin and Texas Red. Suitable chromogenic dyes include diaminobenzidine.

Other reporters include macromolecular colloidal particles or particulate material such as latex beads that are coloured, magnetic or paramagnetic, and biologically or chemically active agents that can directly or indirectly cause detectable signals to be visually observed, electronically detected or otherwise recorded. These molecules may be enzymes which catalyse reactions that develop or change colours or cause changes in electrical properties, for example. They may be molecularly excitable, such that electronic transitions between energy states result in characteristic spectral absorptions or emissions. They may include chemical entities used in conjunction with biosensors. Biotin/avidin or biotin/streptavidin and alkaline phosphatase detection systems may be employed.

The signals generated by individual antibody-reporter conjugates may be used to derive quantifiable absolute or relative data of the relevant antibody binding in samples (normal and test).

The present invention also provides the use of a specific binding

member as above for measuring TGFβ_1 levels in a competition assay, that is to say a method of measuring the level of TGFβ_1 in a sample by employing a specific binding member as provided by the present invention in a competition assay. This may be where the

5   physical separation of bound from unbound TGFβ_1 is not required. Linking a reporter molecule to the specific binding member so that a physical or optical change occurs on binding is one possibility. The reporter molecule may directly or indirectly generate detectable, and preferably measurable, signals. The linkage of

10   reporter molecules may be directly or indirectly, covalently, e.g. via a peptide bond or non-covalently. Linkage via a peptide bond may be as a result of recombinant expression of a gene fusion encoding antibody and reporter molecule.

15   The present invention also provides for measuring levels of TGFβ_1 directly, by employing a specific binding member according to the invention for example in a biosensor system.

     The mode of determining binding is not a feature of the present
20   invention and those skilled in the art are able to choose a suitable mode according to their preference and general knowledge.

     The present invention further extends to a specific binding member which competes for binding to TGFβ_1 with any specific binding
25   member which both binds TGFβ_1 and comprises a V domain including a CDR with amino acid substantially as set out herein or a V domain with amino acid sequence substantially as set out herein. Competition between binding members may be assayed easily *in vitro*, for example by tagging a specific reporter molecule to one
30   binding member which can be detected in the presence of other untagged binding member(s), to enable identification of specific binding members which bind the same epitope or an overlapping

epitope.   Competition may be determined for example using the
TGFβ$_1$ ELISA as described in Example 1.

Preferred specific binding members for TGFβ$_1$ compete for binding
5   to TGFβ$_1$ with CAT 191, CAT 192 and/or CAT 193.

Preferred embodiments strongly neutralise TGFβ$_1$, having a
potency of at least 5 times better than does CS37, more preferably
about 10 times, 15 times, 20 times, 50 times, 75 times, 100 times
10   or 150 times better, in a radioreceptor assay (Lucas C et al
(1991) *Meth in Enzymology* **198**, 303-16). Potency is measure with
the antibody under study and CS37 in equivalent molecular formats,
e.g. as monovalent antibodies (scFv or Fab) or as bivalent
antibodies (IgG1 or IgG4).

15

In one aspect, a specific binding member according to the present
invention binds a peptide including the amino acid sequence of
residues 92-98 of TGFβ$_1$ (the same epitope as CS37).

20   In testing for this, a peptide with this sequence plus one or more
amino acids at either end, may be used.   Such a peptide may be
said to "consist essentially" of the specified sequence. Specific
binding members according to the present invention may be such
that their binding for TGFβ$_1$ is inhibited by a peptide with or
25   including the sequence given. In testing for this, a peptide with
either sequence plus one or more amino acids may be used.

Specific binding members which bind a specific peptide may be
isolated for example from a phage display library by panning with
30   the peptide(s).

The present invention further provides an isolated nucleic acid

encoding a specific binding member of the present invention. Nucleic acid includes DNA and RNA. In a preferred aspect, the present invention provides a nucleic acid which codes for a CDR or VH or VL domain of the invention as defined above.

5

The present invention also provides constructs in the form of plasmids, vectors, transcription or expression cassettes which comprise least one polynucleotide as above.

10   The present invention also provides a recombinant host cell which comprises one or more constructs as above. A nucleic acid encoding any CDR, VH or VL domain, or specific binding member as provided itself forms an aspect of the present invention, as does a method of production of the encoded product, which method
15   comprises expression from encoding nucleic acid therefor. Expression may conveniently be achieved by culturing under appropriate conditions recombinant host cells containing the nucleic acid. Following production by expression a VH or VL domain, or specific binding member may be isolated and/or purified
20   using any suitable technique, then used as appropriate.

Specific binding members, VH and/or VL domains, and encoding nucleic acid molecules and vectors according to the present invention may be provided isolated and/or purified, e.g. from
25   their natural environment, in substantially pure or homogeneous form, or, in the case of nucleic acid, free or substantially free of nucleic acid or genes origin other than the sequence encoding a polypeptide with the required function. Nucleic acid according to the present invention may comprise DNA or RNA and may be wholly
30   or partially synthetic. Reference to a nucleotide sequence as set out herein encompasses a DNA molecule with the specified sequence, and encompasses a RNA molecule with the specified sequence in

which U is substituted for T, unless context requires otherwise.

Systems for cloning and expression of a polypeptide in a variety
of different host cells are well known.   Suitable host cells
include bacteria, mammalian cells, yeast and baculovirus systems.
Mammalian cell lines available in the art for expression of a
heterologous polypeptide include Chinese hamster ovary cells, HeLa
cells, baby hamster kidney cells, NSO mouse melanoma cells and
many others.   A common, preferred bacterial host is *E. coli*.

The expression of antibodies and antibody fragments in prokaryotic
cells such as *E. coli* is well established in the art.   For a
review, see for example Plückthun, A. Bio/Technology 9: 545-551
(1991).   Expression in eukaryotic cells in culture is also
available to those skilled in the art as an option for production
of a specific binding member, see for recent reviews, for example
Reff, M.E. (1993) Curr. Opinion Biotech. 4: 573-576; Trill J.J.
et al. (1995) Curr. Opinion Biotech 6: 553-560.

Suitable vectors can be chosen or constructed, containing
appropriate regulatory sequences, including promoter sequences,
terminator sequences, polyadenylation sequences, enhancer
sequences, marker genes and other sequences as appropriate.
Vectors may be plasmids, viral e.g. 'phage, or phagemid, as
appropriate.   For further details see, for example, *Molecular
Cloning: a Laboratory Manual*: 2nd edition, Sambrook et al., 1989,
Cold Spring Harbor Laboratory Press.   Many known techniques and
protocols for manipulation of nucleic acid, for example in
preparation of nucleic acid constructs, mutagenesis, sequencing,
introduction of DNA into cells and gene expression, and analysis
of proteins, are described in detail in *Short Protocols in
Molecular Biology*, Second Edition, Ausubel et al. eds., John Wiley

& Sons, 1992. The disclosures of Sambrook et al. and Ausubel et al. are incorporated herein by reference.

Thus, a further aspect of the present invention provides a host cell containing nucleic acid as disclosed herein. A still further aspect provides a method comprising introducing such nucleic acid into a host cell. The introduction may employ any available technique. For eukaryotic cells, suitable techniques may include calcium phosphate transfection, DEAE-Dextran, electroporation, liposome-mediated transfection and transduction using retrovirus or other virus, e.g. vaccinia or, for insect cells, baculovirus. For bacterial cells, suitable techniques may include calcium chloride transformation, electroporation and transfection using bacteriophage.

The introduction may be followed by causing or allowing expression from the nucleic acid, e.g. by culturing host cells under conditions for expression of the gene.

In one embodiment, the nucleic acid of the invention is integrated into the genome (e.g. chromosome) of the host cell. Integration may be promoted by inclusion of sequences which promote recombination with the genome, in accordance with standard techniques.

The present invention also provides a method which comprises using a construct as stated above in an expression system in order to express a specific binding member or polypeptide as above.

The following examples illustrate aspects and embodiments of the present invention.

Example 1 Identification of SL15S scFv (CAT-191) and JT182

Example 2 Construction of cell lines expressing the antibody SL15A IgG4 (CAT-192) and SL15S IgG4 (CAT-193)

5

Example 3 Assessment of neutralisation properties of SL15S scFv (CAT-191) and SL15A IgG4 (CAT-192) and SL15S IgG4 (CAT-193)

Example 4 Binding of the antibody SL15S scFv (CAT-191) and SL15A

10   IgG4 (CAT-192) to active and latent TGFβ_1

Example 5 Epitope mapping of the antibodies SL15S scFv and CS37 scFv

15   *EXAMPLE 1*
IDENTIFICATION OF SL15S SCFV (CAT-191) AND JT182

The present inventors have identified antibody CDRs and VH and VL domains related to those of the CS37 antibody disclosed in

20   WO97/13844, but with unexpectedly good properties.

The CS37 VH (31G9) domain sequence and encoding nucleic acid therefor are shown in SEQ ID NO:2 and SEQ ID NO:1, respectively.

25   The SL15 (a.k.a. KYLIE) VH domain sequence of the present invention and encoding nucleic acid therefor are shown in SEQ ID NO:4 and SEQ ID NO:3, respectively.

The respective VH CDR3 sequences are shown in Table 1, also Table

30   2 which includes CDR1 and CDR2 sequences for both VH and VL domains.

Comparison of CS37 (31G9) and SL15 (Kylie) VH domains shows three further differences in framework residues, at residues 1 (glutamine CS37 to glutamate SL15), 6 (glutamine CS37 to glutamate SL15) and 44 (glycine CS37 to glutamate SL15).

5

The SL15 VH domain may be paired with different VL domains, and two such SL15 variants have been identified. One, known as SL15A, includes the CS37 VL. The other, known as SL15S, includes a VL which corresponds to the CS37 VL save for the presence of Serine

10   at residue 25 in SL15S compared with alanine in SL15A (CS37).

The SL15A VL (CS37) domain sequence and encoding nucleic acid therefor are shown in SEQ ID NO:6 and SEQ ID NO:5, respectively.

15   The SL15S VL domain sequence and encoding nucleic acid therefor are shown in SEQ ID NO:8 and SEQ ID NO:7, respectively.

The JT182 VH domain sequence and encoding nucleic acid therefor are shown in SEQ ID NO:10 and SEQ ID NO:9, respectively.

20

SL15S scFv, CS37 scFv and a related antibody JT182 were screened as phage supernatants in ELISA assays for the ability to bind TGFβ_1. ELISA plates (96 well; Falcon) were uncoated, or coated with recombinant TGFβ_1 (0.2 μg/ml). Phage that bound specifically

25   to the antigen coated plate were detected using a sheep anti-fd antiserum (Pharmacia), followed by alkaline phosphatase conjugated anti-sheep (Sigma) and p-nitrophenyl phosphate (pNPP) substrate (Sigma).

30   The scFv fragments were subsequently tested for their ability to neutralise binding of ^{125}I-TGFβ_1 to A549 cells in a radioreceptor binding assay (RRA), using the protocol described in Example 3

(see below). For the RRA, individual clones were expressed as soluble scFv and subsequently purified from periplasmic preparations by immobilised metal affinity chromatography (IMAC) followed by fractionation of monomeric scFv by gel filtration FPLC on a Superdex 75 column (Pharmacia).

SL15 scFv (SL15 VH/SL15 VL) has the highest neutralisation potency in the RRA, having an IC_{50} of 100pM which is at least 100 fold better than CS37. The complete specificity of SL15 scFv for the $TGF\beta_1$ isoform has been confirmed in the TF1 assay where no interaction with $TGF\beta_2$ or $TGF\beta_3$ was detected.

The scFv antibodies SL15S (SL15 VH/SL15 VL; CAT-191 a.k.a. Kylie scFv) and SL15A (SL15 VH/CS37VL) were converted into whole antibody.

EXAMPLE 2
CONSTRUCTION OF CELL LINES EXPRESSING THE ANTIBODY SL15A IGG4 (CAT-192) AND SL15S IGG4 (CAT-193)

For the construction of cell lines expressing human IgG4,κ antibodies, SL15 scFV heavy and light chain variable domains were cloned into mammalian expression vectors containing human IgG4 and human kappa constant domains respectively. Two versions were prepared, SL15A IgG4 (CAT-192) and SL15S IgG4 (CAT-193). The antibodies are also termed Kylie IgG.

Heavy chain expression vector
The VH from the SL15S scFv DNA was PCR-amplified with oligonucleotides P80 (SEQ ID NO:25) and P64 (SEQ ID NO:22) and joined by overlapping PCR to a 159 bp DNA fragment containing a signal sequence, splice sites and intron from M13VHPCR1 (Orlandi

et al., 1989, *Proc. Natl. Acad. Sci. USA* <u>86</u>, 3833-3837) using oligonucleotides P10 (SEQ ID NO:20) and P64 (SEQ ID NO:22). The 558 bp PCR product was cut with HindIII and ApaI and cloned into HindIII-ApaI cut pGamma4 (obtained from Lonza Biologics). Ligated

5   DNA was transformed into *E. coli* TG1 and ampicillin-resistant colonies screened. A plasmid with the correct insertion was identified and designated pKylieVHγ4.

<u>Light chain expression vector</u>

10 The Vκ from the CS37 scFv DNA or from SL15S scFv was PCR-amplified with oligonucleotides P65 (SEQ ID NO:23) and P66 (SEQ ID NO:24) and joined by overlapping PCR to a 168 bp DNA fragment containing a signal sequence, splice sites and intron from M13VKPCR1 (Orlandi et al., 1989, *Proc. Natl. Acad. Sci. USA* <u>86</u>, 3833-3837) using

15 oligonucleotides P11 (SEQ ID NO:21) and P66 (SEQ ID NO:24). The 510 bp PCR product was cut with BstBI and BsiWI and cloned into BstBI-BsiWI cut pMR15.1. Ligated DNA was transformed into *E. coli* TG1 and ampicillin-resistant colonies screened. A plasmid with the correct insertion was identified and designated pCS37κ or

20 pKylieκ.

<u>Tandem expression vector</u>

A single plasmid containing both heavy and light chain DNAs and the gs selectable marker was constructed for each of the Kylie

25 variants. The heavy chain vector, pKylieVHγ4, was digested with BamHI and NotI and the 4497 bp fragment containing H chain DNA purified. The light chain vector, pCS37Vκ or pKylieκ, was similarly cut with BamHI and NotI and the 9611 bp fragment containing L chain DNA was isolated. The two purified fragments

30 were ligated together, transformed into *E. coli* TG1 cells and ampicillin-resistant colonies screened. A plasmid with the correct insertions was identified and the V regions confirmed by

sequencing.   The   final   expression   vector   was   designated
pKylieg4γs. Two versions were prepared containing SL15S VL or CS37
VL.

5   <u>Expression of SL15S IgG4 and SL15A IgG4</u>

SL15S IgG4 and SL15A IgG4 were expressed in the mouse myeloma cell
line NSO (ECACC 85110503). Fifty μg of pKylieg4γs were linearised
by digestion with PvuI, ethanol precipitated and dissolved in 100
μl water. 10^7 NSO cells were washed in PBS, resuspended in 0.9 ml

10 PBS, mixed with the vector DNA and held in ice for 5 min. The
cells were then electroporated with a single pulse of 250 V at 960
μFd and incubated in ice for 10 min. The transfected cells were
then added to 30 ml Dulbecco's modified Eagle's medium (DMEM)
containing 2 mM glutamine and 10 % dialysed foetal calf serum

15 (FCS) as described by Bebbington et al. (1992) Bio/Technology **10**
169-175, and 50 μl aliquots distributed into 6 x 96-well plates.
24 h later glutamine-free DMEM/10 % FCS (Bebbington et al. 1992)
was added to each well.

20 Three to six weeks after transfection colonies were screened by
ELISA for the ability to secrete human IgG. Wells of ELISA
plates (Immulon 4, Dynatech) were coated in 50 mM sodium
bicarbonate/carbonate pH 9.6 with 100 ng per well of goat
anti-human IgG antibodies (Harlan).   Supernatant from wells

25 containing transfected colonies was added to the wells in PBS
containing 0.05 % (v/v) Tween 20 (PBST) for 1 h. The plates were
washed 3 times with PBST and captured human IgG was detected with
100 μl 1:2000 dilution horseradish peroxidase (HRP)-conjugated
goat anti-human kappa antibodies in PBST (Harlan). After 30 min

30 at room temperature the plates were washed 3 x PBST and 100 μl OPD
substrate added.   Reactions were stopped after 5-10 min by the
addition of 50 μl 12.5 % (v/v) sulphuric acid and the A 490 nm

measured.

Transfectants secreting the highest amounts of IgG were expanded
for growth in glutamine-free medium in reduced FCS, in
gammaglobulin-free FCS or no FCS. Cell lines were subsequently
cloned by limiting dilution.

Purification of IgG

Human IgG4 antibodies were purified by protein A affinity
chromatography followed by size-exclusion chromatography (SEC).
Supernatant from the growth of transfected NS0 cells secreting IgG
was clarified by centrifugation and filtration through a $0.22 \mu m$
membrane. A column of protein A Sepharose Fast Flow matrix
(Pharmacia) was equilibrated with 0.3 M NaCl, 50 mM sodium
phosphate pH8.0 and the supernatant applied. The column was then
extensively washed with 50 mM sodium phosphate pH 8.0. Human IgG
was eluted with 0.1 M glycine-HCl pH3.0. Eluted fractions were
neutralised with 1 M Tris HCl pH 9.0 and protein containing
fractions identified by measuring the absorbance at 280 nm.
Purification by SEC was on a Superdex 200 column in PBS. The IgG
was finally concentrated by diafiltration against pyrogen-free PBS
using a YM30 MWCO filter (Amicon).

EXAMPLE 3

*ASSESSMENT OF NEUTRALISATION PROPERTIES OF SL15S SCFV (CAT-191)
AND SL15A IGG4 (CAT-192) AND SL15S IGG4 (CAT-193)*

The potency of neutralisation of $TGF\beta_1$ was measured for SL15S scFv
(Kylie scFv) and its derivatives using a radioreceptor assay and
a cell proliferation assay (TF1).

MATERIALS

$[^{125}I]$ TGFβ_1 was supplied by Amersham (specific activity range 800-2200Ci/mmol). Recombinant human TGFβ_1, β_2, β_3, latent TGFβ_1, GM-CSF and IL-5 were obtained from R&D Systems (Minneapolis USA). Genzyme murine mAb against TGFβ_1, β_2 and β_3 was obtained from Genzyme (Cambridge, MA, USA). The TF1 cell line was supplied by Robin Thorpe (NIBSC, UK) and cultured as detailed below. The A549 human lung epithelial carcinoma cell line was obtained from ATCC and grown in DMEM with 10% FCS and 2mM glutamine. All other reagents were supplied by Sigma.

METHODS

Radioreceptor assay

A549 cells were seeded into 24-well plates at 2×10^5 cells per well for 24 hours in order to achieve >90% confluency. Immediately before the assay, monolayers were washed twice with buffer (1:1 DMEM:Hams-F12) and 0.5ml assay buffer (1:1 DMEM:Hams F12 + 0.1% BSA) was added. Two or three-fold serial dilutions of antibodies were prepared in assay buffer and added to an equal volume of 40pM $[^{125}I]$ TGFβ_1 in assay buffer.

After 1 hour at room temperature, 0.5ml of this antibody/$[^{125}I]$ TGFβ_1 mixture was added in duplicate to the cells (already in 0.5ml assay buffer) and incubated for 1 hour at 37°C. Final concentration of $[^{125}I]$ TGFβ_1 was 10pM. Controls were included as maximum binding (to cells, no antibody) and minimum binding (wells incubated with buffer but no cells) in at least triplicate.

Finally plates were washed 4x with ice-cold PBS before 0.8ml solubilisation buffer (25mM Tris pH 7.5, 10% glycerol, 1% Triton x100) was added. Plates were left for at least 20 minutes on a

rocking platform before the contents of each well were counted using a gamma counter.

Data were expressed after subtraction of minimum binding, as % of maximum binding.

In the study using latent TGFβ_1, % maximum was calculated for each set of conditions (eg in the presence of latent TGFβ_1, acid-activated latent TGFβ_1 or active TGFβ_1).

(Lucas C et al (1991) *Meth in Enzymology* **198**, 303-16)

TF1 assay

TF1 cells were routinely grown in RPMI1640 containing 5% FCS and 2 mM glutamine (growth medium) with 2ng/ml GM-CSF. Immediately before the experiment, cells were washed twice and resuspended at 4×10^5 cells/ml in fresh medium supplemented with 4ng/ml IL-5 either with or without TGFβ_1, β_2 or β_3 (each at 50pM) and 100μl aliquots transferred to 96-well plates. scFv preparations used in this assay were FPLC-purified fractions which had endotoxin removed.

Antibodies (two fold dilution series) were prepared in growth medium and 100μl added to cells in duplicate. Controls were cells with TGFβ only (no antibody, maximum inhibition of growth) and cells with no TGFβ and no antibody (minimum inhibition). Cells were incubated for 48 hours at 37°C.

At the end of the assay cell number was assayed using CellTiter96 (Promega) and data expressed as % neutralisation i.e.:

% neutralisation = $\dfrac{\text{(test value - maximum inhibition)}}{\text{(minimum inhibition - maximum inhibition)}}$ x 100

In the study of latent TGFβ$_1$, data were expressed as % of control
(growth in the absence of TGFβ$_1$) as the amount of active TGFβ$_1$ in
each test condition varied.

5   (Randall LA et al (1993) *J Immunol Meth* **164**, 61-7)

Production of antibodies
ScFv antibodies and IgG4 antibodies were prepared and purified as
described above.

10

RESULTS

Potency of SL15S scFv (CAT-191) and SL15A IgG4 (CAT-192) in a
bioassay (TF1 assay)

15   The ability of SL15S scFv (CAT-191) to recognise TGFβ$_1$ but not
TGFβ$_2$ or β$_3$ in the TF1 assay was investigated.

SL15S scFV (also known as Kylie scFV) neutralised the growth
inhibition induced by TGFβ$_1$ but not that induced by TGFβ$_2$ or TGFβ$_3$
20   (Figure 1). As a control, a monoclonal antibody, Genzyme Mab
1.D.11.16, was used (Genzyme, Dasch, J.R., et al, J. Immunol.,
142, 1536-1541, 1989), which neutralises TGFβ$_1$, TGFβ$_2$ and TGFβ$_3$.
Mab 1.D.11.16 has been shown to be effective in models of lung
fibrosis, radiation induced fibrosis (Barcellos-Hoff, US Patent
25   5616561, 1997) and rheumatoid arthritis (Wahl et al, J. Exp.
Medicine, **177**, 225-230, 1993).   SL15S scFv shows comparable
potency to the Genzyme Mab 1.D.11.16 control against TGFβ$_1$.

The activity of SL15A IgG4 (CAT-192; also termed Kylie IgG4) was
30   also shown in the TF1 assay (Figure 5b) in the study using latent
TGFβ$_1$.

<u>Potency of SL15S scFv (CAT-191), SL15A IgG4 (CAT-192) and SL15S</u>
<u>IgG4 (CAT-193) in the radioreceptor assay</u>
The ability of SL15S scFv to recognise TGFβ_1 and neutralise
binding of TGFβ_1 to A549 cells was measured in the radioreceptor
5   assay.

In a comparison of his-preps of scFv, SL15S (Kylie) was compared
to the parental antibodies CS37 and JT182 (Figure 2) and was found
to be 100- to 150-fold and 10-fold more active. SL15 was
10   reformatted as IgG in two forms, SL15A IgG4 (CAT-192) and SL15S
IgG4 (CAT-193). Purified preparations of SL15S scFv, SL15A IgG4,
SL15S IgG4 and Mab 1D.11.16 (Genzyme mAb) were also analysed
(Figure 3).

15   SL15S scFv has comparable potency to the Genzyme Mab 1.D.11.16,
which is effective in animal models. In summary, SL15S scFv is
a highly potent, neutralising antibody for TGFβ_1, with IC$_{50}$ values
in the range 0.03 to 0.1nM.

20   *EXAMPLE 4*
BINDING OF THE ANTIBODY SL15S SCFV (CAT-191) AND SL15A IGG4
(CAT-192) TO ACTIVE AND LATENT TGFβ_1

The experiments described in this example demonstrated that SL15S
25   scFv and SL15A IgG4 bind to and neutralise active, but not latent,
TGFβ_1.

Latent TGFβ_1 is the biologically inactive form in which TGFβ_1 is
secreted from cells, and is composed of a latency associated
30   peptide dimer (consisting of two 249 amino acid monomers) and a
mature TGFβ_1 dimer (consisting of two 112 amino acid monomers).
Latent TGFβ_1 is not recognised by cell surface TGFβ receptors.

Active TGFβ_1 is thought to be released by the action of proteases *in vivo* which can be mimicked by acidification *in vitro*.

Latent TGFβ_1, has a reported ED50 of 0.43nM and 2pM before and
5   after acidification respectively, as assayed in a proliferation
assay. Active TGFβ_1 has a reported ED50 in a proliferation assay
of approximately 2pM. Presumably the effect of latent TGFβ_1
before acidification is due to the presence of some active TGFβ_1.
This residual activity must be considered on interpretation of the
10   results.

The potency of SL15S scFv and SL15A IgG4 was tested using the
radioreceptor assay and TF1 proliferation assay in the presence
of varying amounts of latent TGFβ_1, acid-activated TGFβ_1 and
15   active TGFβ_1. If the antibodies recognise latent TGFβ_1, their
potency should be reduced. Interpretation of both assays is
complicated by the fact that any active TGFβ_1 present in the
latent preparation will compete with [^{125}I] TGFβ_1 for binding and
have biological activity on the cells.
20

Latent TGFβ_1 was acid-activated by the addition of 2μl 0.5M HCl to
1ml latent TGFβ_1 for 15 min at room temperature then neutralised
with 43μl 0.05 M NaOH/0.01 M Hepes.

25   Results show that in the radioreceptor assay there is no
significant effect of latent TGFβ_1 (0.1nM) on the potency of SL15S
scFv (Kylie scFv) or SL15A IgG4 (Kylie IgG), whereas
acid-activation of the latent TGFβ_1, or an equivalent
concentration of active TGFβ_1 reduces the ability of the antibody
30   to neutralise [^{125}I] TGFβ_1 binding (Figure 4).

The TF1 proliferation assay was very sensitive to the activity of

the active TGFβ₁ in the latent TGFβ₁ preparation. Nevertheless, the SL15S scFv or SL15A IgG4 were found to be able to neutralise the small proportion of active TGFβ₁ of the latent preparation and when the latent TGFβ₁ is acid-activated neutralise this effectively (Figure 5).

Therefore, SL15, in the scFv or IgG format, binds and neutralises only active but not latent TGFβ₁ as measured by both the radioreceptor and the TF1 neutralisation assay.

EXAMPLE 5
EPITOPE MAPPING OF THE ANTIBODIES SL15S SCFV AND CS37 SCFV

In this example the epitope on TGFβ₁ to which the antibodies CS37 and SL15S binds was determined.

TGFβ₁ and TGFβ₂ have similar structures but differ in their binding affinity for the TGFβ type II receptor and their potency in a number of biological assays (O.G. Ottmann & L.M. Pelus J. Immunol. 140 2661-2665, 1988; J.R. Merwin et al Am. J. Pathol. 138 37-51, 1991; K.C. Flanders et al Development 113 183-191, 1991; L. Suardet et al Cancer Res. 52 3705-3712, 1992). Qian et al (J. Biol. Chem. 271 30656-30662, 1996) have taken advantage of the differences in affinity to identify the key residues involved in the high affinity binding of TGFβ₁ to the type II receptor. This has been done by making a series of chimeric molecules between TGFβ₁ and TGFβ₂ and identifying those species which retain high affinity receptor binding *in vitro* (Qian et al, supra) and *in vivo* (J.K. Burmester et al Growth Factors 15 231-242, 1998). In this way, the C terminal region encompassed by residues 83-112 of TGFβ₁ was identified as sufficient to retain efficient receptor binding.

Comparison of the sequences of TGFβ_1 and TGFβ_2 identified several differences including a loop consisting of residues 92-98, which includes 4 amino acid differences between TGFβ_1 and TGFβ_2. When these residues from TGFβ_2 were introduced into a TGFβ_1 backbone,

5   receptor binding was greatly reduced, identifying these as key residues in the interaction of TGFβ_1 with the type II receptor.

The chimeric molecules were used in a similar way to map the binding site of CS37 and SL15S scFv (CAT-191) on TGFβ_1. TGFβ_1/β_2

10   (83-112) corresponds to the N-terminal and central region of TGFβ_1 from residues 1-82, fused with the C-terminal region of TGFβ_2 from residues 83-112. TGFβ_2/β1 83-112 corresponds to the N-terminal and central region of TGFβ_2 from residues 1-82, fused with the C-terminal region of TGFβ_1 from residues 83-112. Finally, TGFβ_1-β_2

15   (40-112) corresponds to the N-terminal region of TGFβ_1 from residues 1-39, and the central and C-terminal region of TGFβ_2 from residues 40-112. These are referred to hereafter as 1-1-2, 2-2-1 and 1-2-2 respectively, to reflect the relative composition of the isoforms.

20

These three molecules along with TGFβ_1 and TGFβ_2 were profiled for inhibition of binding of SL15S scFv and CS37 scFv to immobilized TGFβ_1 as follows.

25   Phage displaying SL15S scFv or CS37 scFv were prepared from clones in pCANTAB6, by M13K07 superinfection. Phage were PEG precipitated and resuspended in PBS containing 2% Marvel. Phage (2.5 to 5 x 10^{10} in 50μl) was added for 30 minutes to a preblocked ELISA plate coated with TGFβ_1 at 0.5μg/ml.

30

For inhibition analysis, the same concentration of phage was used and a dilution series of TGFβ concentrations set up for each of

the TGFβ chimeric molecules described above (Gift from J. Burmester, National Institutes of Health) and the TGFβ$_1$ and 2 isoforms.

5   These were incubated overnight at 4°C before adding to the ELISA plate. Phage that bound specifically to the antigen coated plate were detected using a sheep anti-fd antiserum (Pharmacia), followed by alkaline phosphatase conjugated anti-sheep immunoglobulin (Sigma) and p-nitrophenyl phosphate (pNPP)
10   substrate (Sigma).

The uninhibited value (i.e. 0nM) for Kylie was 1.67 (Average of 3 readings) and for CS37 was 1.216 (Average of 7 readings). The result shown in Figures 6 and 7 indicates that the epitopes
15   recognised both by CS37 scFv and SL15S scFv reside between residues 83-112 of TGFβ$_1$. Furthermore, the mutant molecule TGFβ$_1$-β$_2$(92-98) which comprises TGFβ$_1$ with the TGFβ$_2$ sequence from residues 92-98 also inhibits CS37 and SL15S scFv binding to TGFβ$_1$ but with reduced effect, especially for SL15S scFv. This
20   demonstrates that at least part of the epitope recognised by these antibodies resides within the region 92-98, (which has four residues, at positions 92, 94, 95 and 98, which differ between TGFβ$_1$ and TGFβ$_2$).

25   *EXAMPLE 6*
ACCELERATION OF CORNEAL EPITHELIAL WOUND HEALING IN THE PRESENCE OF THE ANTI-TGFb1 MONOCLONAL ANTIBODY SL15A IgG4 (CAT-192)

TGFβ has been implicated in the modulation of wound healing (both
30   ocular and dermal) and has been shown to inhibit the rate of corneal re-epithelialisation. Here the effect of topical application of SL15A IgG4 (CAT-192) on the rate of corneal

56

epithelial wound healing was assessed using an organ culture model (DM Foreman et al., Exp. Eye Res. 62, 555-564, 1996.

Excisional trephine wounds (5mm diameter, 250μm depth) were created on bovine corneas. Corneal scleral rings were maintained in a serum-free, air-interface organ culture system for up to 96hr. At time of wounding, and twice daily thereafter, 100μl of serum-free T8 medium was added dropwise to the epithelial surface and limbus, containing: (i) 10ng/ml TGFβ_1; (ii) 100μg/ml anti-TGFβ_1 mAb; (iii) a combination of (i) and (ii); (iv) 100μg/ml null antibody (2G6 IgG4); (v) 100μg/ml antibody diluent; or (vi) no additions (n = 9 for each group). Re-epithelialisation was assessed using an image analysis system and expressed as percentage of the original wound area covered by epithelium.

Control corneas that received medium alone, null antibody or antibody diluent demonstrated complete re-epithelialisation by 72hr. Treatment with 100μg/ml of anti-TGFβ_1 mAb increased the rate of re-epithelialisation such that corneas were completely re-epithelialised by 48 hours (Figure 8). Corneas treated with 10ng/ml TGFβ_1 demonstrated delayed re-epithelialisation by 24 hours and this inhibitory effect was abolished by anti-TGFβ_1 mAb (Figure 9). All differences quoted are significant ($p<0.05$). Linear regression was performed on the data points between 2 and 48h (see Figure 8) to determine the rate of re-epithelialisation. CAT192 caused a significant increase in this variable (Table 3). Histological analysis supported the image analysis results and confirmed that addition of anti-TGFβ_1 mAb did not adversely affect corneal architecture.

Table 3. The effect of CAT192 or TGFβ₁ on the rate of re-epithelialisation of bovine isolated cornea in air interface organ culture following excisional trephine wound.

Treatment	Rate of Re-epithelialisation (% h⁻¹)	n
Medium 199 (100μl)	1.56 ± 0.07	8
Vehicle (100μl)	1.57 ± 0.08	8
Null antibodyIgG4 (10μl)	1.48 ± 0.09	8
TGFβ₁ (1ng)	1.01 ± 0.09τ	8
CAT192 (10μl)	2.11 ± 0.09*	8

Table 3 legend: Bovine cornea were treated with 100μl of either serum free Medium 199 (control) or medium containing vehicle (for antibody and TGFβ₁) null IgG4 isotope-matched antibody, TGFβ₁ or CAT192 immediately after wounding and at 12h intervals thereafter. Linear regression was performed on the data points between 2 and 48h (see Figure 8) to determine the rate of re-epithelialisation. CAT192 caused a significant increase in the rate of re-epithelialisation of wounded bovine cornea whereas TGFβ₁ caused a significant decrease in this variable. Values shown are the mean value and the s.e.mean. The effect of the different treatments was compared using one way ANOVA with Tukey test. *$P<0.01$ compared to the null antibody treatment group; τP0.01 compared to the vehicle treated group.

These results confirm the important role of endogenous TGFβ₁ in corneal epithelial repair and provide indication that the topical application of the anti-TGFβ₁ mAb SL15A IgG4 (CAT-192) may be used to promote improved wound healing *in vivo*.